FLORISTIC AND ECOLOGICAL STUDIES ON THE LOW ALTITUDE GRASSLANDS OF THE COASTAL REGION OF THE WESTERN GHATS

Synopsis of the thesis to be submitted to Mangalore University for the award of the degree of

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By

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SYNOPSIS OF THE DOCTORAL THESIS

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I. INTRODUCTION

Grassland is the most extensive terrestrial biome, occupying 41–56 × 106 km^2, or 31–43 percent of Earth's surface (White, et al. 2000). Important aspects of low land plateaus with respect to medicinal plants, microhabitats and narrow endemics are discussed by various researchers (Madhu et al,2013; Sreejith et al,2016; Pramod and Pradeep,2021).

Studies on population of grassland using quadrat method has been done by various researchers (Solbrig et al. 1980; Fenner,1998; Wang et al.,2002, Parmar et al. 2012; Rao et al.,2012; Bhat and Ghate,2000) Floristic studies in lateritic plateaus have reported occurrence of many endemic species and habitat-specific flora (Bachulkar 1983; Yadav & Sardesai 2002; Watve 2013; Rahangdale & Rahangdale 2014; Joshi & Janarthanam 2004; Rahangdale & Rahangdale, 2018). Explorations by Joseph and Sivarajan (1990); Madhusoodanan and Singh (1992) have given deeper insights into floristic diversity of grassland plateaus.

Some of the new species discovered from low altitude plateaus in the recent years include *Rotala malabarica* (Pradeep et al. 1990), *Nymphoides krishnakesara* (Joseph & Sivarajan 1990), *Justicia ekakusuma* (Pradeep & Sivarajan 1991), *Lepidagathis keralensis* Madhu. &

Singh (Madhusoodanan & Singh 1992), *Rotala tulunadensis* (Subhrahmanya et al.,2012), *Eriocaulon gopalakrishnanum* (Rashmi and Krishnakumar.,2012), *Eriocaulon madayiparnese* (Swapna et al. 2012), *Blyxa mangalensis* (Rashmi and Krishnakumar,2016), *Blyxa kasaragodensis* (Biju,2016) etc., emphasize the rich diversity in these grassland plateaus. These studies highlight the importance of grassland ecosystems in terms of floral diversity and species richness.

Though many endemic and new species have been reported from the lateritic hills and grassland plateaus, floral inventory of these ecosystem are limited (Jayarajan 2004; Balakrishnan et al. 2010). Number of endemic taxa and species richness varies in each plateau (Thorpe et al 2018; Lekhak and Yadav,2012; Rao et al., 2012; Rhangdale & Rahangdale,2014). Rahangdale & Rahangdale (2014), stated that even closely related plateaus differ considerably in species composition.

Microhabitat classifications are done by few earlier researchers (Porembski et al. 1994, 1997, 2000; Seine et al. 1998; Jacobi et al. 2007). A detailed account of microhabitat categorization for rock outcrops is already available as given by Lekhak &Yadav (2012), Watve (2013), Rahangdale & Rahangdale (2014). Plant species commonly seen in the microhabitats have been recently discussed by Watve and Thakur (2006), Larseon et al., (2005), Watve (2013), Watven (2013i) Sreejith et al., (2016), Porembski & Barthlott (2000), Thorpe et al., (2018) with some modifications.

Seasonal variation in herbaceous plants

Quadrat and seasonal succession studies revealed the complex diversity pattern variations depending on pre monsoon to post monsoon seasons. The growing season starts with dominance of ephemerals and then later this is replaced by perennials. Both, the number of species and number of individuals declines after a peak at the beginning of the growing season (Biswell et al., 1956; Augustine & Longe, 1984; Joshi and Janarthanam, 2004; Hanif et al., 2007; Subhash Chandran et al.,2012).

According to Lekhak and Yadav (2012), based on the phenology of the plants, successional phases can be recognized. However, few observations on phenological trends have been made out by Watve (2007), Sreejith et al., (2016), Rahangdale and Rahangdale (2014). These patterns of occurrence and their phenology (frequency, duration and time) in the community is influenced directly or indirectly by climatic factors like photoperiod, temperature, humidity and rainfall/precipitation (Opler et al., 1980; Van Schaik et al., 1993; Bach, 2002; Bawa et al., 2003). Seasonal fluctuations in appearance of herbaceous plants are often correlated with

environmental factors such as rainfall patterns (Milton, 1980; Bach, 2002; Ramesh & Pascal,1991; Sivaraj & Krishnamurthy,1989; Martinkova et al.,2000). Timing of fruiting phenology is also well studied in connection with different abiotic factors. This relationship with temperature and rainfall was studied by Lesica and Kittelson (2010), Nakar et al., (2011).

- **Aims**

The goal of this study was to characterise floristic composition and to emphasise the importance of grassland plateaus in low-elevation areas. A foundation of scientific knowledge on the ecological relevance of low altitude grassland plateau is required to develop conservation and management strategies for this terrain, particularly at a time when habitat destruction is at an all-time high.

- **Objectives**

I. Floristic studies on the low-altitude grassland.

II. To record rare, threatened and endemic species.

III. Quantitative and qualitative ecological studies on plant diversity to evaluate the importance of grassland for habitat conservation.

IV. To study the phenology and seasonal succession of the flora of these grasslands.

II. <u>Outline of thesis</u>

This work comprises of 5 chapters i.e, Introduction, Review of literature, Materials and methods, Results, Discussion and conclusion.

- **Materials and Methods:**

Field work days are categorized into - Pre-monsoon phase (May), Monsoon phase (June-September) and Post Monsoon phase (October-November), Cold-dry phase (December-April). Since heavy monsoon period support maximum growth of grassland therophytes, July and September were ideal months for 90% of the collection. Konaje plateau (Fig.1) was selected exclusively for phenology and succession studies. The data on latitude and longitude

was recorded and calibrated with Google Earth 6.2 (http://www.google.com/earth/index.html). Each plateau was GPS marked. Regular field works were conducted during different season between 2011 and 2016 to study the floristic comosition**.** Photographs are taken by using NIKON DSLR D5600 camera and flower parts photographs were taken by using Nikon sterio binocular microscope.

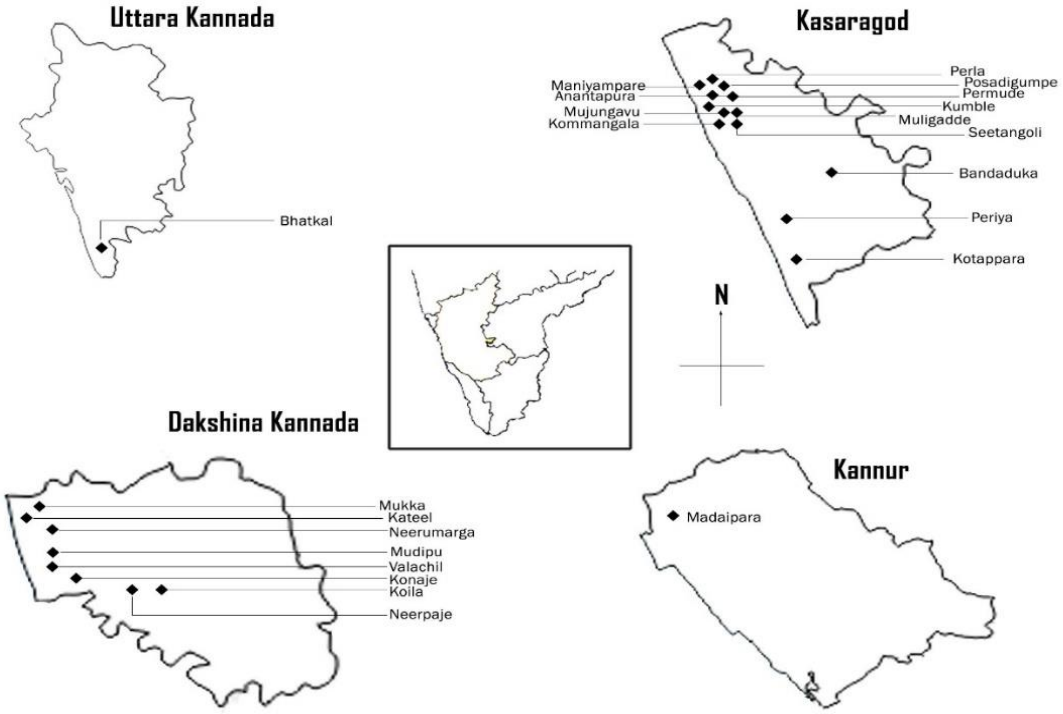

Figure 1: Location map of study areas

- **Identification of plants:**

Plants were identified by using relevant local and regional floras (Gamble,1915- 1936; Yoganarasimhan and Razi, 1982; Ramaswamy & Razi,1973; Ramaswamy et al., 2001; Bhat, 2003 & 2014; Ingalhalikar, 2007), revisionary works (Janarthanam &Henry,1984; Ansari &

Balakrishnan,1994 & 2009; Thiv,2003; Shahina and Nampy,2014) and online services. Identity of each specimen was compared with protologues and types deposited in various herbaria such as G, K, M, N, P (online services).

Data on distribution of species and accepted names were followed by using websites:

http://www.plants of the world online.org., www.ipni.org,worldfloraonline.org/taxon/wfo.,

http://www.worldfloraonline.org.

- **Raunkiaers life forms and conservation status**

Life-forms have been classified as per Raunkiaer (1934). The status of the species was assigned as per the IUCN Red List Categories and Criteria Version 3.1 (IUCN, 2021).

- **Preparation of Herbarium**

The herbarium specimens were prepared as per standard specification (Fosberg & Sachet, 1965; Bridson & Forman, 1991).

- **Study on vegetation composition**

The herbaceous plant species were recorded with in the representative quadrats.
Sampling design: Following standardization, the quadrat size was fixed at 1 sq. meter while the minimum number of quadrats was found to be 10 for each estimation. In each selected area 10 quadrats of 1m×1m, were laid along a straight line (transect line), leaving a distance of 10 m between any two successive quadrats.

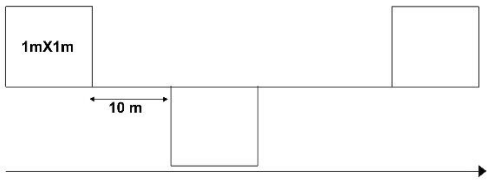

Figure 2: Line transact outline for this study.

- **Distribution pattern of plants**

Based on distribution of herbaceous taxa in the Laterite Rock Outcrops (LRO's), we have considered two categories in the present work. They are, i) Plateau specificity of species, ii) Species specific to microhabitats.

- **Diversity indices**

Shannon –Weiner index (H) and Simpson's index were calculated. Along with this Species richness index (R), Evenness_EH/S, Brilliouin index (HB), Menhinick (M), Margalef's index, Evenness, Fisher-alpha, Berger_Parker, Equitability, Chao_1, Density, Frequency, Abundance, IVI were also calculated.

- **Classification of microhabitats**

The microhabitats were classified based on overall appearance, edaphic properties, water availability and species composition. All existing classifications attempted in other rocky plateaus of Western Ghats and other regions were referred while classifying microhabitats (Porembski & Barthlott, 2000; Jacobi et al. (2007); Aparna Watve,2013; Lekhak and Yadav,2012; Sreejith et al,2016).

The microhabitats classified were further analysed for their similarity in species composition by Sorensen's Similarity index using the formula:

Sorensen's Similarity index S=2C/(A+B)

Where S= Similarity index; A= number of species in sample A; B= number of species in sample B; C=number of species in sample common to A and B.

- **Soil analysis**

Following parameters were taken for soil analysis:

- PH- Using digital PH meter.
- Total nitrogen by Kjeldal method (1883)
- Available phosphorous by Bray et al (1945) method
- Availability of Potassium by flame photometer
- Organic Carbon by Wakley and Black Method (1934)

- **Phenology**

Selection of plants and data sources: A total of 26 representative species from different types of microhabitats from various families have been selected for study. These belong to 16 families, containing 5 species of Poaceae, 3 species of Lentibulariaceae, 2 species of

Asteraceae and Eriocaulaceae each and 1 species each from Burmanniaceae, Droseraceae, Rubiaceae, Lythraceae, Commelinaceae and Fabaceae.

The starting date for a given phenophase was observed from a permanently marked individual selected from a group of more than ten individuals. Infected or injured plants were avoided from the study. Vegetative phase was observed from germination stage to fully developed mature leafy stage. Flowering was determined by first opened flower seen on any tagged plant and considered as the first flowering day for that particular specimen of the species, while the last flowering day was when only a single flower remained on any tagged plant of the species. In the case of first fruiting day, initiation of fruit on any tagged plant of the species was considered, whereas ripening of fruit was considered as the last fruiting day. Finally, mean value of all tagged plants was converted into mean data for each species for a particular phenological trait, viz. first flowering day (FFD) and first fruiting day (FFRD) etc.

- **Seasonal succession**

A total of 57 species were recorded from permanent sample plots. In every data collection, only plants exhibiting flowering phenology were selected. Certain species are likely to have dominating appearance in particular phases of succession and they tend to appear in other phases also. To avoid confusions in interpretations their presence is continuously recorded in each phase.

- **Analysis of Data**
  - **Canonical analysis:**

To analyse the relationship among environmental variables, herbaceous species and sampling sites, we performed a canonical correspondence analysis (CCA) using MVSP version 3.11.

- **Cluster analysis (CA)**

Morista similarity analysis: To verify the degree of similarity between sampling sites, considering taxonomic richness and floristic abundance, we performed a modified Morista similarity analysis (UPGMA method, MVSP version 3.11).

For clustering similar sampling units of monsoon flora showing succession stages, chord distance co-efficient method was used. Computation was carried out using a PAST program and dendrograms prepared.

- **Principal component analysis (PCA)**

PCA was carried out using the package PAST version 2.16. The central deal of principal component analysis is to reduce the dimensionality of the data set consisting of large number of interrelated variables, while retaining as much as possible.

- The data is presented mainly by using graphs and tabular columns and photographs.

All descriptive statistics, average, standard deviation, minimum and maximum were obtained using MS Excel-2010.

III.Results:

3.1.1: Floristic composition in the study region

Analysis of the floristic diversity in the Southern coastal grassland plateaus resulted in recording a total of 393 herbaceous species. Of the flora documented, 43.9 % were monocots and remaining 54.7% eudicots. Herbaceous plants recorded were belonging to 25 orders, 188 genera and 54 families. 7 orders are from monocots, and 17 are from eudicots especially super rosids and superasterides.

Altogether herbs (71.6 %), shrubs (7.16 %), climbers (9.31 %) and trees (11.8%) contribute to the flowering plants of this ecosystem. The most speciose-families in the plateaus are Poaceae followed by Fabaceae and Rubiaceae with high number of Therophytes.Some of the genera in the plateaus are characteristically species rich. Families with largest number of herbaceous genera were Poaceae, Asteraceae followed by Fabaceae. *Eriocaulon* has the highest number of species (14), followed by *Dichanthium* (12), *Ischaemum* (11). Spatial distribution of plant species in the study region is given in **Figure 3**.

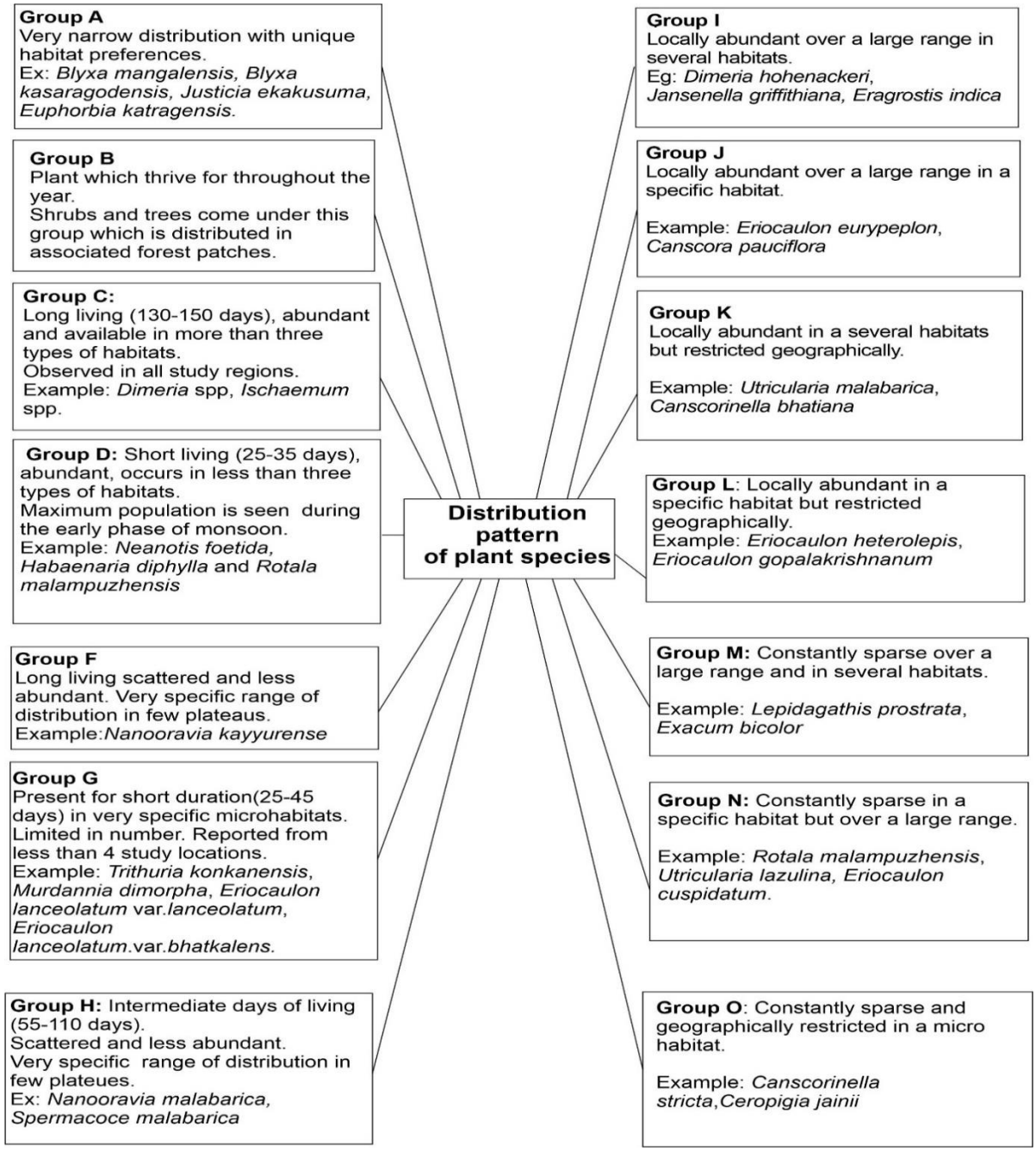
Group A
Very narrow distribution with unique habitat preferences.
Ex: Blyxa mangalensis, Blyxa kasaragodensis, Justicia ekakusuma, Euphorbia katragensis.
Group B
Plant which thrive for throughout the year.
Shrubs and trees come under this group which is distributed in associated forest patches.
Group C:
Long living (130-150 days), abundant and available in more than three types of habitats.
Observed in all study regions.
Example: Dimeria spp, Ischaemum spp.
Group D: Short living (25-35 days), abundant, occurs in less than three types of habitats.
Maximum population is seen during the early phase of monsoon.
Example: Neanotis foetida, Habaenaria diphylla and Rotala malampuzhensis
Group F
Long living scattered and less abundant. Very specific range of distribution in few plateaus.
Example:Nanooravia kayyurense
Group G
Present for short duration(25-45 days) in very specific microhabitats.
Limited in number. Reported from less than 4 study locations.
Example: Trithuria konkanensis, Murdannia dimorpha, Eriocaulon lanceolatum var.lanceolatum, Eriocaulon lanceolatum.var.bhatkalens.
Group H: Intermediate days of living (55-110 days).
Scattered and less abundant.
Very specific range of distribution in few plateues.
Ex: Nanooravia malabarica, Spermacoce malabarica
Distribution pattern of plant species
Group I
Locally abundant over a large range in several habitats.
Eg: Dimeria hohenackeri, Jansenella griffithiana, Eragrostis indica
Group J
Locally abundant over a large range in a specific habitat.
Example: Eriocaulon eurypeplon, Canscora pauciflora
Group K
Locally abundant in a several habitats but restricted geographically.
Example: Utricularia malabarica, Canscorinella bhatiana
Group L: Locally abundant in a specific habitat but restricted geographically.
Example: Eriocaulon heterolepis, Eriocaulon gopalakrishnanum
Group M: Constantly sparse over a large range and in several habitats.
Example: Lepidagathis prostrata, Exacum bicolor
Group N: Constantly sparse in a specific habitat but over a large range.
Example: Rotala malampuzhensis, Utricularia lazulina, Eriocaulon cuspidatum.
Group O: Constantly sparse and geographically restricted in a micro habitat.
Example: Canscorinella stricta,Ceropigia jainii

Figure 3: Spatial distribution of plant species in the study region.

3.1.7: α- Diversity indices

When compared with the diversity indices among the study sites, Madayipara is the most species rich having Shannon diversity index H=3.456 and Simpson value D= 0.9556 followed by Bhatkala with Shannon diversity index H=3.898, and Simpson value D= 0.9534.

Koila plateau was less species rich with Shannon diversity index H=2.157, and Simpson value D= 0.5834.

3.1.8: Morista β-diversity indices

Analysis of the niche sharing of different species between study sites by calculating Morista index (Figure 3.6) revealed the existence of two groupings. The first grouping was formed by two large plateaus (Madayiara and Bhatkal) with 42% similarity. This grouping shared the plants belonging to *Utricularia*, *Eriocaulon*, *Crotalaria*, *Geissaspsis*, *Dimeria*, *Jansenella*, *Ischaemum* etc. The second grouping was linked to small plateaus of different study regions, where Neerumarga and Konaje shared similar types of habitats with good number of hydrophytes. For example, *Trithuria konkanensis*, *Blyxa mangalensis* and *Crotalaria quinquefolia* are common here. *Rauvolfia serpentina*, *Eriocaulon lanceolatum*, *Aristolochia indica* are common in Valachil and Koila plateaus. Maniyampara and Anathapuram shared *Pogostemon* spp and *Rotala* spp. The sampling sites that were most related in perennial composition were Kotappara and Periya; they shared *Brachystelma* spp and few lesser known medicinal species.

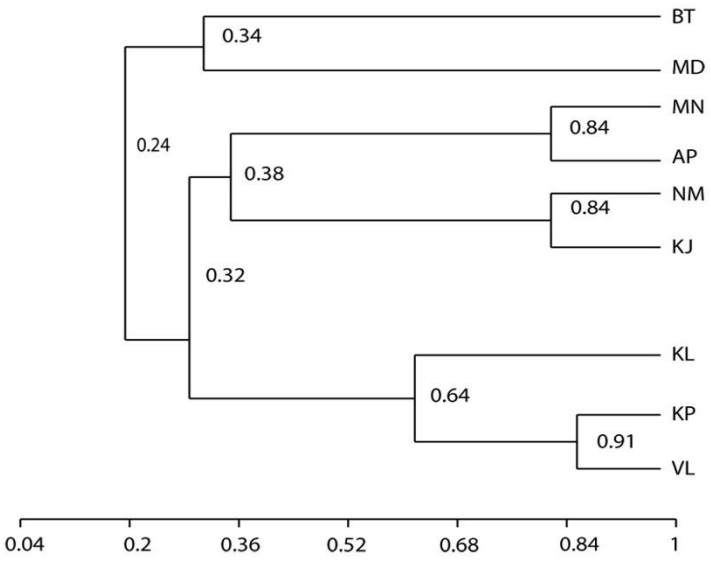

Figure 4: Modified Morisita's Cluster showing similarity in species composition.

3.1.10: Principal component analysis

Principal component of biodiversity showed three possible groups (Figure 5). The results shows that the first axis had 48.8% of cumulative variance followed by second axis 19.7%. Rare and Endemic species composition played major role even though some plateaus share similar environmental and spatial structure, still they accommodate distinct floristic composition.

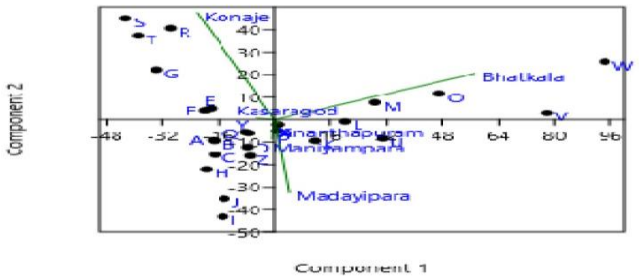

Figure 5: Multiple component analysis of selected important monsoon species a general view on important monsoon flora distribution.

3.2.1: Rarity and endemism:

Out of 396 herbaceous species recorded in this study, 95 are Western Ghats endemics; of which 25 are narrow endemics of Kerala and Karnataka, confined to low altitude grassland plateaus. 41 species are Indian endemics and 23 species are endemic to Peninsular Indian and Sri Lanka. 75 species are in Least Concern (LC) category as per the IUCN Red List Categories and Criteria Version 3.1 (IUCN, 2021). Two species each are Data Deficient (DD) and not evaluated (NE) while two species are Critically Endangered (CR), 2 are Endangered (EN), one species is nearly threatened.

3.3.1: Microhabitats and species representation:

We have categorised 9 macrohabitats each of these may have 1-5 types of microhabitats (Table.1).

Macrohabitat	**Microhabitats**
I.Cryptogamic mat surfaces (CS)	I.a: Cryptogamic vegetation on flat/ small loose rock surfaces
	I.b: Cryptogamic vegetation on Large Rock Boulders (LB) with Highly

	exposed areas to sunlight
	I.c: Tree trunk surfaces
II. Vegetation of rock crevices (RC)	II.a: Small Rock crevices on exposed rock surfaces
	II.b: Rock crevices continuous channel like depth up to 10 cm
III.Water pools (WP)	III.a: Ephemeral temporary rock Pools
	III.b. Wide and deep Seasonal ponds (depth up to 1 meter or more)
	III.c: Shallow edges of ponds
IV.Streams (S)	IV.a: Vegetation of small seasonal water channels (Slow water flow)
	IV.b: Vegetation of long and deep seasonal water channels (Speedy water flow)
V.Soil filled areas (SFA)	V.a: Wide and open surfaces with varying soil depth
	V.b: Ephemeral Flush Vegetation (EFV)
	V.c: Rocky slopes filled with small soil depressions (RSD)
	V.d: Edges rocks and boulders
	V.e: Marshy areas
VI. Rock boulders (RB)	VI.a: Large Rock Boulders (LRB) with shady areas and small caves
	VI.b: Large rocky slopes and boulders in open areas (RS)
VII.Wide and open Grassy hill slopes (GS)	VII: Wide undulate areas
VIII. Forest covers and shrub patches	VIII.a: Shrubs and climber association inside the plateau
	VIII.b: Forest covers and associated flora (FCA)
IX. Disturbed areas	IX.a: Vegetation of Drainage channel
	IX.b: Weed affected areas (Construction/Dumping site/road side/plantation crops)

Table 1: Classification of Microhabitats.

3.3.2: The similarity index

The similarity index between these communities varied from 0-0.50. 24 combinations were possible when 9 communities were compared between each other for their similarity in species composition, but interestingly only 2 microhabitats were found to have more than 50% similarity which clearly indicates the diversity of habitats in grassland plateaus. On the other hand, few microhabitats found 100% dissimilar. Temporary pools (TMP) and cryptogamic vegetation on rock surfaces were found to be the two communities, which show more dissimilarity with remaining communities. (Table 2).

	CS	S	RC	LRB	GS	SFA	WP	RS	DA
CS		0[b]	0.04	0.03	0[b]	0[b]	0[b]	0[b]	0[b]
S			0[b]	0[b]	0[b]	0.065	0.55	0[b]	0[b]
RC				0.60	0.30	0.53	0[b]	0.28	0.06
LRB					0.03	0.046	0[b]	0.43	0[b]
GS						0.48	0[b]	0.04	0.12
SFA							0.03	0.20	0.23
WP								0[b]	0[b]
RS									0.25
DA									

Table 2: Similarity index value between microhabitats of study region.

Note: [a]microhabitats having more than 50% similarity; [b]microhabitats which are 100% dissimilar.

3.3.3: Diversity indices

The Shannon diversity index (H) ranged from 2.10 to 3.68. The highest Shannon diversity index was recorded in Soil Rich Areas (3.68) followed by Rock crevices (3.55) and temporary water pool (2.66). The Simpson index of dominance ranged from 0.0328 to 0.1738. The highest Simpson index was recorded in soil filled areas (0.1738) followed by temporary water pool (0.1616), Rock Boulders (0.1306) and Streams (0.1286).

The species richness index in different microhabitat of the study area ranged from 0.0776 to 0.3372. The highest species richness index (R) was recorded in Soil Rich Areas (0.3372) followed by Rock crevices (0.1457) and Grassy slopes (0.1489). Disturbed area also represented Shannon Index (2.98), Simpson Index (0.0967), Species Richness Index (0.1356).

3.3.4: Overall microhabitat representation in different plateaus

Each grassland plateaus are different in their microhabitat representation. These can vary in size, shapes and species composition based on geographical conditions, intensity of rainfall, topography and various other ecological factors. In each study region, 3-4 types of microhabitats are dominantly seen compared to other types. For example: One part of Bhatkal represents rocky hills with negligible amount of soil, whereas another part consists of plain

lands with deep soil filled areas**.** Small rock crevices and cryptogamic vegetation is also observed. However, deep-water pools or streams are rarely seen.

Kateel and Mukka region shows soil rich areas mixed with patches of forest cover. Konaje, Neerumarga and Mudipu plateaus are characteristic with seasonal ponds with good number of endemic species. Rock crevices, different types of soil-filled areas, shrub patches and forest covers are common. Valachil plateau consist of rocky boulders and soil rich areas in edges of rocks. Koila plateau is known for its undulated and wavy stretches of grassy slopes with little of lateritic content in the soil. Plateau stretches of Kasaragod district share similar habitats with unique representation of *Strychnos* forest patches and laterite rich grasslands. Ananthapuram plateau shows slant rocky plateau stretches, which provide unique ecological niche for distinct species composition. Posadigumpe consist of lateritic hillock region intermingled with forest patches and shrubs. Kommangala plateau is made up of wide and plain laterite stretches with abundant rock crevices with less soil in it. Kotappara and Bandadka share similar kind of habitats with a kind of rich ephemeral flush vegetation and rock crevices. Perla and Puttur region also share similar kind of habitats. Madayipara Plateau shows all types of habitats over a very large stretch (nearly 600 acres) of the grassland area.

3.3.5: Soil analysis

PH varied from 6.2-6.8 and E.C showed values ranging from 0.2-1.4. Soil varied from sandy-to-sandy loam type with good water holding capacity and normal EC. It was highly acidic (4.5–6), rich in organic carbon, available nitrogen and available potassium.

Rare and Endemic species distribution with reference to microhabitats

Soil filled areas and Rock crevices filled with soil have shared maximum number (29) of endemics (Table 3).

I	2							
II	0	8						
III	0	0	9					
IV	0	0	5	6				
V	1	29	2	3	15			
VI	0	2	0	1	7	1		
VII	0	6	0	0	4	2	0	
VIII	0	1	0	0	7	0	0	0

IX	0	0	0	0	1	0	0	0	17
	I	II	III	IV	V	VI	VII	VIII	IX

Table 3: Distribution of herbaceous endemics in different microhabitats of LROs of study area.

IV.Phenological variation in selected plants of permanent plot study.

Reproductive phenology of 26 species showed that generally 80% of the species start vegetative phase in middle of June – July end and remaining species germinate at the beginning of September. While 65.4% species flower during July end to august end.70% of the species start fruiting at the beginning of September. In the first year of study, 2012–13, 40.8% of the species showed flowering in September followed by 39.9% in August, although 19.3% of the species showed flowering in October and November. The year 2012–13 showed highest flowering (55.38%) in August followed by (45.2%) in September.

But there was a drastic decrease in flowering during 2014-2016. During the five study years 2011–12 and 2012–13,2013-14,2014-15,2015-16 the percentage of species in fruiting was 76.9, 88.5 and 84.6,80.2,72.9 respectively. During December -January only 0.76% herbaceous species showed reproductive phenology. Pooled analysis of the data exhibited the highest average flowering (76.9%) in September on 2012; however, average highest fruiting (83.3%) was recorded in October 0n 2013.

On the basis of flowering, 2 species were identified with long flowering duration whereas 21 species were identified with short flowering duration. In the case of fruiting, 3 species showed long fruiting duration and 14 species comes under short fruiting duration (Table 4).

Type	Approx. no. of days	No of sp
Species with long vegetative duration	120-180	2
Species with medium vegetative duration	35-65	4
Species with short vegetative duration	Less than 30 days	20
Species with long flowering duration	53-69	2
Species with medium flowering duration	43-50	3
Species with short flowering duration	9-30	21
Species with long fruiting duration	35-53	3
Species with medium fruiting duration	16-34	9
Species with short fruiting duration	10-31	14

Table 4: Categorization plants based on number of days for phenological events.

Linear correlation between temperature and percentage of species for the number of days for vegetative, flowering as well as fruiting was non-significant; however, average values (taking mean values of all 5 years) had significant association with environmental fluctuations.

Flowering and fruiting phenology varied significantly ($P < 0.01$) for more than 8 species. Mean values of percentage of species in flowering event indicated highest peak in August followed by September; the highest peak for fruiting (83.3%) was observed in October followed by November (57.7%). *Eriocaulon euripeplon, Sophubia delpinifolia, Drosera indica, Lindernia ciliata, Utricularia malabarica, Cyanotis cristata, Ramphicarpa longifolia, Canscora pauciflora* germinates soon after the onset of monsoon season and completes their life cycle within a very short period of time. *Lepidagathis prostrata*, *Ischemum indicum*, *Arundinella metzii*, *Blumea oxydonta* exhibited prolonged duration of vegetative phenology depending on the climatic factors.

Dimeria hohenackeri showed highest pooled average of 79 and 189 days for flowering. However, *Neonotis foetida* pooled the lowest average of 16 flowering days. Highest and lowest pooled average number of fruiting days were recorded for *Crototalaria quinquifolia* and *Utricularia reticulata* with 56 and 15 days/year respectively. Average deviation in flowering among all species was 15.5 days from the first to second year of study; however, this was 15.4 days for the second to third year, resulting in overall 16.4 days of deviation for the entire study period. In the case of fruiting, the deviation was 20.7 and 17.3 days, from the first to second year and second to third year, whereas the pooled deviation was 19 days in fruiting.

The results reveal that there is a significant difference in the different phases of the phenology for *Sopubia delpinifolia*, *Murdannia smepteris*, *Eriocaulon eurypeplon*, *Lepidagathis prostrata*, *Drosera indica*, *Cyanotis cristata*, *Glyphochloa acuminata*, *Polygala elongata*, *Alysicarpus bupleurifoilius*, *Dimeria hohenackeri*, *Arundinella metzii*, *Burmania pusilla*, *Justicia procumbence* (P=.001)

However, with respect to *Jansenella griffithiana* (P=0.11), *Utricularia uliginosa* (.374), *Alysicarpus bupleurifoliua*, *Neanotis foetida* (.147), *Rotala malabarica* (.568), *Lindernia ciliata*, *Justicia procumbens* (0.907), *Utricularia reticulata* (0.049) no difference between the phases of phenology was observed.

Yearwise, there was no significant differences in the mean life of *Lepedagathis prostrata*. It might be due to the drought enduring capacity of the species. But certain species showed

significant results, *Utricularia reticulata* (0.008), *Lindernia ciliata* (0.028), *Neanotis foetida* (0.002), *Utricularia uliginosa* (0.012) it might be due to the fluctuation in environmental factors like rainfall, humidity and Temperature.

Species	Model	R	R Square	Adjusted R Square	ANOVA p value	Prediction: Dependent/Independent on phases
Sop-delp	1	.689(a)	.475	.431	.000	Dependent
Murd-sem	1	.882(a)	.777	.758	.000	Dependent
Erio-eury	1	.708(a)	.502	.460	.000	Dependent
Jans-grif	1	.409(a)	.167	.098	.111	Dependent
Lep-prost	1	.995(a)	.990	.989	.000	Dependent
Utr-ret	1	.472(a)	.223	.158	.049	Dependent
Lind-cil	1	.431(a)	.186	.118	.085	Not dependent
Droc-ind	1	.873(a)	.761	.741	.000	Dependent
Cya-crist	1	.765(a)	.584	.550	.000	Dependent
Dim-hohn	1	.849(a)	.721	.697	.000	Dependent
Ramp-long	1	.648(a)	.419	.371	.001	Dependent
Can-pauz	1	.899(a)	.809	.793	.000	Dependent
Rot-mal	1	.215(a)	.046	-.033	.568	Not dependent
Erio-chem	1	.635(a)	.403	.353	.002	Dependent
Ish-ind	1	.930(a)	.864	.853	.000	Dependent
Burm-pus	1	.814(a)	.662	.634	.000	Dependent
Blum-oxt	1	.965(a)	.932	.926	.000	Dependent
Utr-purp	1	.819(a)	.670	.643	.000	Dependent
Poly-corym	1	.946(a)	.894	.885	.000	Dependent
Neo-foet	1	.384(a)	.147	.076	.147	Not dependent
Aly-bup	1	.685(a)	.469	.425	.001	Dependent
Just-proc	1	.090(a)	.008	-.075	.907	Not dependent
Arun-metzi	1	.961(a)	.924	.918	.000	Dependent
Pol-elong	1	.731(a)	.534	.495	.000	Dependent
Utr_ulig	1	.280(a)	.079	.002	.374	Not dependent
Gly-acum	1	.743(a)	.552	.515	.000	Dependent

Predictors: (Constant), Veg. phase, Frt. phase, Fl. phase

Table .5: Prediction of individual species dependency over climatic fluctuations

V.Seasonal succession

Early phase of monsoon (June-July) was period of vegetative growth of main taxa which contribute greatly to the biodiversity. Early monsoon facilitates the germination of perennating tubers and rhizomes. During August and September, different plant community stages with significant flowering phenological patterns were seen. Poaceae members starts

germinating when nongrass ephemerals diversity reaches the peak. The species richness as well as diversity declined again in the post monsoon (October), but now grasses will be reaching seed setting phase. Few Acanthaceae perennials were seen in the winter and summer period with unique habitat specific adaptations.

Temporary water pool (Site II) and Soil filled depressions (site III) region are maximum species rich having Shannon diversity index and Simpson value i.e., D = 0.89 & 0.93 respectively on heavy monsoon phase. In the weed disturbed region, diversity index values are lowered drastically, with Simpson value ranging from 0.16-0.60 and Shannon diversity index 0.38-0.4. This is due to the dominant ruderal species *Spigelia anthelmia*. Whereas, grassy hill slopes are usually dominated by few Poaceae members in the late succession stages with Simpson index value and Shannon diversity index ranging from 0.56-0.60 and 0.30 -2.28 respectively.

Cluster analysis also revealed successional patterns of different plant communities. The dendrogram recognized different sets of species groups contributing towards seasonal succession.

VI. Highlights

- The dominant species found in most of the study region were *Eragrostis indica*, *Dimeria hohenckeri*, *Impatiens minor*, *Eriocaulon euripeplon* etc.
- The family Poaceae has largest number of endemic species (25 species), followed by Fabaceae, Eriocaulaceae and Apocynaceae. *Eriocaulon* represented highest endemic species followed by *Dimeria* and *Ischaemum*. Monocots dominate the endemic composition of the monsoon herbaceous flora.
- Madayipara and Bhatkal showed high species diversity followed by Konaje plateau.
- Comparing taxa with allied taxa has resulted in, describing two new taxa *Eriocaulon gopalakrishnanum* (Rashmi and Krishnakumar, 2012) and *Blyxa mangalensis* (Rashmi and Krishnakumar, 2017), a new vareity *Eriocaulon lanceolatum* var.

bhatkalens (Rashmi and Krishnakumar, 2021) and *Hedyotis kurzii* (Rashmi and Krishnakumar, 2015), a new report to Peninsular India.

- Eight major adaptations seen in the study region particularly carnivory, succulence, poikilohydry, subterranean perennating organs, hydrophytes, parasitism, vegetative propagation and, production of seeds. Habitat specificity of species, Mat-forming and mass flowering plants were also noted.
- An analysis on the life-form reveals that nearly 56.5 % of the species recorded were Therophytes, followed by Phanerophytes (19.72 %), Chaemephytes (5.56%), Hemicryptophytes (4.66 %) and Cryptophytes (5.56 %).
- Plant communities in the study region were continuously changing with respect to change in rainy season and other environmental factors. Each species found in successive stages were adapted to specific climatic conditions.
- The growing season began with ephemerals and later this plant cover initially decreased, remained dominant during heavy monsoon season, then began a linear decrease in diversity by retaining a few important grass species. During seasonal succession, different plants species occurred in varying abundances that reveal fluxes in their pattern of establishment in different years. During heavy monsoon phase, species occurrence and replacement takes place rapidly. Over the second phase of succession, establishment of perennial plants limited opportunities for annual species to establish themselves. Since sufficient rainfall during July -October months lead to conducive situations for rejuvenation of old rootstocks.

- Phenological variations shows a clear relationship of group of plants with environmental conditions like humidity, rainfall and temperature.
- Pollination services, ethnobotanical significance, temporary pools were some of the uses/ecosystem services of plateaus.
- The low altitude plateaus face numerous threats, including a lack of thorough and extensive investigation, exotic invasion, fire and afforestation programmes.
- Due to the impossibility of habitat restoration in this circumstance, the report presents mainly a few important recommendations: Habitat conservation, pallam conservation, and species conservation through the participation of local communities in sustainability, monitoring, and education about ecosystem services. Scientists can promote awareness and contribute to scientific understanding of habitats by scientifically enumerating the flora and implementing practical research projects.

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